Mr. Percival Lowell, of Flagstaff, Arizona, read a paper on "Explanation of the Supposed Signals from Mars of December 7 and 8, 1900."

The following annual reports were read :—

The report of the Treasurer.

The report of the Curators.

The report of the Hall Committee.

The report of the Publication Committee.

The report of the Library Committee.

The meeting was adjourned by the presiding officer.

EXPLANATION OF THE SUPPOSED SIGNALS FROM MARS OF DECEMBER 7 AND 8, 1900.

BY PERCIVAL LOWELL.

(*Read December 6, 1901.*)

1. On a certain morning in December, 1900, paragraphs appeared in the papers throughout the United States with the startling announcement that Mars had been signaling the Earth the night before. Lights, it was reported, had suddenly shone out upon the surface of the planet, lasted for a time and then vanished. What the signals meant was not so forthcoming. Vividness of headline made up for meagreness of news.

Interest was not confined to the United States. Reportorial inquisitiveness was as rife in the Old World as in the New, and Europe was behind America in the receipt of the message only the time necessary for its transmittal.

2. To broaden one's horizon is a good thing; and to broaden it beyond the bounds where horizon itself disappears, a still better one. But the broadening is apt to come not in a way we expect, and to prove the more broadening for that reason. I hope, therefore, not seriously to lessen interest in the phenomena by saying that they were certainly not what they were popularly taken to be, and were with equal certainty much which was not supposed and is quite as interesting.

The innocent cause of the misrepresentation was a dispatch sent

from Flagstaff to the writer and communicated by him through the usual channels to the astronomical world. The signaling part of it was a tale added by journalistic ingenuity at the time that profession became possessed of the subject. The original dispatch read:

> "Projection observed last night over Icarium Mare, lasting seventy minutes."
> (Signed) "DOUGLASS."

3. Projections in the case of one heavenly body, the Moon, are not unfamiliar objects. On almost any night when that body shows a terminator, that is a sunset or sunrise edge, a keen eye can detect one or more of them along it without telescopic aid. With Mars the phenomenon is much less common and, though many such projections have in the last few years been seen upon the planet, the sight is one of some rarity.

4. In the case of the Moon it is possible to find out the cause of the projections. By magnification through a telescope the little knob that breaks the otherwise uniform boundary of light and shade is seen to resolve itself into the tip of a mountain peak or the summit of a crater wall, which catches the light while the lower ground at its foot is plunged in shadow, and so seems to project beyond the rest of the disk. With Mars no such forthright determination of the problem is possible. For no magnification we can apply is potent enough to disclose of itself the character of the country. We are, therefore, obliged to reason upon what we see.

5. Taking lunar analogies for guide, it was generally inferred that the martian projections too were due to mountain peaks. From which of course it followed, or as one may say preceded, that there were mountains on Mars. But the Flagstaff observations of 1894 showed that, on general principles, this was very improbable. The study of the surface markings led the writer to a general theory about the character of the planet, in which mountains not only found no place but to which they were decidedly opposed. At the same time that the theory suggested itself, but independent of it, Mr. Douglass observed several projections, and conceived and published another explanation for them, and this one proved consonant with what the theory demanded, to wit: that, instead of being due to mountains upon the planet's surface, they were due to clouds floating in the planet's air. He showed that the observations were thus much better explained; in fact, that his observations could hardly be accounted for with probability on the mountain hypothesis at all

6. The opposition of 1894 was very prolific of projections, over four hundred being seen at Flagstaff in the course of nine months. The next opposition was not so good; while in that which has just passed, that of 1900–1, only two were detected. It was these two which gave rise to the notion of signals from the planet.

Now the variability in the number seen at different oppositions should have materially shaken faith in the mountain explanation. Mountains are permanent affairs, and if they be high enough to catch the light and show as protuberances at one time they should do the like at another. The change in the inclination of the disk would not materially alter their visibility. But it is one of the humorous anomalies about human nature that general reasoning affects minds so little when applied to unfamiliar matters, while in familiar ones it is the guiding principle of life.

7. Argument from the two projections of the last opposition is, on the other hand, particular. Although they were but two in number, testimony in the case is very much to the point. Indeed, their isolated character helps to make their cogency the clearer.

On December 7, at 16h. 15m. S. M. T., Mr. Douglass suddenly noticed a projection on the terminator of the planet, a little to the north of the Sabæus Sinus. The phase loss at the time was 36°.4. As he continued to watch it the projection increased. The distance of its tip from the edge of the terminator passed successively through the values ⅔, 1, 1⅓ and 1½ of a thread; the thread used being the stationary spider's thread of the micrometer. Meanwhile he was busy taking the position angle of the tangent to the terminator, at the point directly under it, at intervals of a few minutes. His observations, recorded in detail in the observing book, are as follows:

RECORD OF DECEMBER 7, 1900.

Th. = thread; P.A. = position angle.

1900.	
Dec. 7, 16h. 15m.	Projection over Sinus Sabæus; P.A. tang. to terminator 183°.2
22m.	Projection continues (sketch). Height = ⅔ Th.
24m.	P.A. terminator tang. 185°.5.
26m.	P.A. terminator tang. 184°.3.
30m.	Projection continues; ½ to ¾ Th. in height.
34½m.	P.A. terminator tang. 182°.4.
37½m.	Ht. 1 Th.; no other irregularities on terminator.
39m.	P.A. 182°.0.
41m.	P.A. 184°.7.

Dec. 7, 16h. 42½m. Rather bright cn terminator near north cap at P.A. 238°.0.
44m. Projection continues; terminator otherwise regular.
46m. P.A. 183°.8.
51m. (After spell of seeing 0) projection then of this form: (sketch). Height 1⅓ Th.
P.A. 183°.9.
55m. Projection there; flatter?
59m. Projection there; flatter?
17h. 6m. Projection there (after spell bad seeing) (sketch); possible separation. Height 1½ Th.
P.A. 186°.2.
19m. Think projection is very small; at times thought it gone. Now ⅓ Th. (sketch).
22m. Projection certainly there; I get this form: (sketch) Sinus Sibæus? Very low, say ¼ Th.
P.A. 185°.3.
30m. Think the projection has gone or else it is very slight; if it is there its P.A is 186°.0.
35m. Projection undoubtedly gone.

8. On the next night he found the terminator perfectly regular until 15h. 44m. S. M. T., when he recorded: Terminator regular, but suspicious white N. of Icarium Mare. Icarium Mare is a name given to the dark marking running from the forks of the Sabæus Sinus to the Hammonis Cornu, and formerly included under the general designation of the Sabæus Sinus. Four minutes later he noted: Projection just started N. of Icarium Mare. There then followed an almost exact repetition of the previous night's experiences, as will be seen from the transcript of the observations.

Record of December 8, 1900.

Th. = thread; P.A. = position angle.

1900.
Dec. 8. 15h. 44m. Terminator regular, but a suspicious white N. of Icarium Mare.
48m. Projection just started N. of Icarium Mare.
50m. At P.A. 186°.3. Ht. ½ Th.
All, so far, was with eyepiece .89.
I now put in ¾ ep.
58m. Projection more conspicuous. Ht. ⅔ Th.
P.A. 184°.8.
16h. 02½m. Projection. Ht. ⅔ Th. shows more easily in this ep. than .89.
16m. Projection at P.A. 187°.7; seeing good for limb and terminator.

Dec. 8, 16h. 20m. The projection looks separated from term.; seeing not good enough to assume this (sketch).

25m. Projection looks separated in good seeing. Ht. 1½ Th., and half of this is separated (sketch). P.A. 188°.1.

34m. Projection P.A. 187°.0; in ½ inch; seeing poor.

44m. Projection probably there at P.A. 187°.7, and of this form (sketch) and faint; seeing is constantly too poor to judge well.

47m. Projection; think it is there as described. The terminator has been otherwise regular at all observations.

50m. Seeing 1–2. Think projection is there, low and faint, and also a whitish region on adjoining disk.

9. On reducing and comparing the observations of the two nights, it appears at once that they do not refer to the same point or points upon the planet. On the first night, at the time of the appearance of the projection, the longitude of the centre of the disk was 26°, at the time of its disappearance 44°, while on the next evening the longitudes were respectively 10° and 25°. Not only were the two positions not the same, but they were separated from one another by at least sixteen degrees of longitude.

10. On looking up the records of the first night, it appears that the planet, previous to the detection of the projection, was under continuous observation from 14h. 10m. to 15h. 45m. S. M. T., or from the time the longitude of the centre was 355° to the time it was 18° During this interval there are two specific records that the terminator was free from irregularity, one at 14h. 31m., the other at 14h. 45m.; and from the nature of the observations it is presumable that any projection occurring in the interval would not have escaped notice. We may then fairly infer that the projection seen on December 8 did not exist in that position on December 7.

11. On December 8 observations ceased at 16h. 50m., but on the 12th of the month the terminator was carefully scrutinized from longitude centre 298° to longitude centre 13° at intervals, such that no projection of the duration of those of the 7th and 8th could have passed it without being seen. No irregularity was detected. The projection of December 8, therefore, did not exist *in situ* on the 12th.

12. Furthermore, when the rotations of the planet and the Earth brought the two bodies again into corresponding positions at corresponding hours on January 12, the terminator was scanned by Mr. Douglass from 13h. 48m. to 15h. 35m., or from longitude centre 15°

to longitude centre 41°, without revealing any irregularity. The phase loss was then 27°, as against 36° in December. So that nine degrees should be deducted from these figures to make them comparable. It thus appears that on this date both projections should have been visible, one after the other, had they still existed. Neither was seen. Nor was any projection seen at any other time during the opposition. Permanences like mountains, therefore, could not have caused them without doing violence to the observations.

From the impermanency of place of the projections it is clear that they could not have been fixed to the planet's surface—that is, they could not have been mountains. We are left, therefore, with the alternative that they were a something floating in the planet's air capable of reflecting light, or in other words clouds. Secondly, from the similarity of their appearances, we infer that they were the same clouds which had shifted their position during the twenty-four hours that elapsed between their apparitions. They may, of course, have been wholly distinct condensations of vapor which happened to agree in behavior. The probability of this we shall now investigate by considering the phenomena more in detail.

13. It is necessary to begin by determining their height, for it will be found that this height enters as a function into the equations of position. If we call

$d =$ the perpendicular distance of the tip of the projection from the terminator;

$P—P. A. = \varphi =$ angle between the tangent to the terminator and the axis of rotation;

$E =$ the angle of the phase;

$A =$ the phase latitude, that is the latitude reckoned from the phase equator;

$a =$ the radius of the disk in seconds of arc;

$a_0 =$ the radius of the planet in miles;

$x =$ the angle subtended at the centre of the disk between the tip of the projection and the point on the terminator at the same phase latitude,

we shall have

$$\tan x = \frac{d}{\cos \phi \sin E. a. \cos A}$$

and $h =$ height will be

$$h = \sec x - 1. a_0 \cos {}^2 A$$

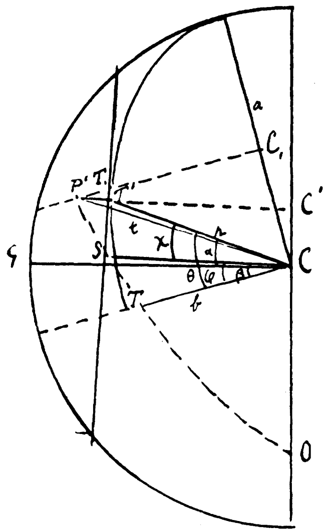
Performing the numerical operations, we find for the height on December 7,

$$h = 13.4 \text{ miles.}$$

and on December 8,

$$h = 13.6 \text{ miles.}$$

14. For the calculation of position we proceed as follows:



b

$$\operatorname{Tan} \theta = \frac{a^2}{b^2} \operatorname{Tan} \varphi$$

$$r^2 = \frac{a^2}{\sin^2\theta + \frac{a^2}{b^2}\cos^2\theta}$$

$$t^2 = r^2 + h^2 + 2rh\cos\chi$$

$$\frac{\sin TCP'}{\sin\chi} = \frac{h}{t}$$

$$\chi = \theta - \varphi$$

$$\alpha = \theta - \beta$$

$$C = 90^\circ + \alpha - TCP'$$

Let θ = angle which the line from the centre of the phase ellipse to the point upon the terminator perpendicularly under the projection makes with the minor axis of that ellipse. Let r = distance from the centre of the disk to this point. The minor axis has for value $r \cos E$, the major axis being r. By a property of the ellipse we have

$$\tan \theta = \frac{a^2}{b^2} \tan \phi = \sec^2 E \tan \phi$$

from which we find θ. To find r we have from the equation of the ellipse

$$r^2 = \frac{a^2}{\sin^2\theta + \frac{a^2}{b^2}\cos^2\theta}$$

from which, knowing θ, the value of r follows.

The distance t from the centre to the tip of the projection may now be got by solving the plane triangle whose sides are d, r and t. For d is given, r is now known and the angle included between them is $180° - \chi$ where

$$\chi = \theta - \phi$$

and this also is known.

t would give us the projected place upon the visible disk of the tip of the projection, if the projection were on the surface of the planetary sphere. As it is in reality raised above it, we must apply a correction depending upon the height of the projection. It is for this reason that the height must first have been found. Perhaps the neatest way is the one adopted by Mr. Manson, who performed the numerical computations, that of simple projection, which gives

$$t_1 = \frac{a}{a+h}\,t$$

Knowing t and also the angle in the plane triangle opposite the side d, which we may call D, we have a spherical triangle for the determination of the latitude and longitude of the point on the sphere directly under the projection. In this triangle we know the side t, whose value in angular measure is cos t; the side $(90°B)$, which is the angle between the pole of the planet and the centre of the disk; and the angle between the two, which is

$$\begin{aligned} C &= 90° - (Q - 270° - P) + \theta - D \\ &= P - Q + \theta - D \end{aligned}$$

where P and Q have the meanings of Crommelin's ephemeris for the planet.

We then have the latitude, l_1, from

$$\cos l_1 = \cos t_1 \sin B + \sin t_1 \cos B \cos C$$

and the longitude, λ, from

$$\frac{\sin(\lambda - \lambda_1}{\sin C} = \frac{\sin t_1}{\sin T_1}$$

The results are:

PROJECTION DECEMBER 7, 1900.

TABLE I.

Date.	*h.*	*m.*	*P.A.*	*d.*	*Lat.*	*Long.*
Dec. 7........	16	15	183°.2	⅓ thread	—4°.7	333°.1
	17	06	186°.2	1½ "	—3°.6	339°.4
	17	19	186°.1	⅓ "	—1°.5	347°.4
	17	30	186°	0 "	—1°.0	351°.4

and for

PROJECTION DECEMBER 8, 1900.

TABLE II.

Date.	*h.*	*m.*	*P.A.*	*d.*	*Lat.*	*Long.*
Dec. 8........	15	50	186°.3	½ thread	—1°.9	315°.2
	16	25	188°.1	1½ "	—1°.4	319°.5
	16	44	187°.1	½ "	—0°.8	328°.5

15. The numerical value of *d* was got as follows: Mr. Douglass' micrometric measures of the spider's thread were obtained by moving the movable thread from contact on the one side of the stationary thread to contact on the other. This gave 0".22 for the width of a thread.

In the estimating of the distance *d* the thread was placed against the background of the disk. As a measure of width it was therefore its true width less the irradiation into it from both sides. The value of this irradiation was determined by the following device which occurred to me, and which if accurately made should give the irradiation absolutely. From the point of contact the thread is moved till the bright background seems equal to the width of the thread. We then have the following equation, in which

$a =$ width of thread.
$b =$ width moved from contact to one apparent thread apart.
$x =$ the irradiation.

$$a - 2x = b + 2x.$$

or

$$x = \frac{a - b}{4}$$

b proved $= 0''.14$

whence the effective width of the thread was 0".18.

The P.A.'s used were got either directly or by plotting all the P.A.'s taken and then drawing the centre of gravity line between them.

16. The first thing that appears from the tables is that the observations cannot be satisfied by the supposition of one cloud alone on either day. It is necessary to suppose two on each occasion, a high cloud followed by a much lower one. The height of the lower cloud was about three to four miles, and it lay to the west and north of the main one.

The eastward end of the main cloud on December 7 was in latitude 4°.7, longitude 333°; its westward end in latitude 3°.6, longitude 339°. So that the cloud either stretched this distance or moved over it in the interval. From the great speed required it is unlikely that the cloud actually travelled this distance in this time. If translation took place at all, it was probably the translation of propagation. But, from the phenomena of the next night, it would seem more likely that the cloud really stretched over 6°, or 220 miles. Its breadth was ½ thread or 0″ 09, which is forty-five miles.

The dimensions of the subsidiary cloud, or subsidiary portion of the main cloud, are much more conjectural. It would seem to have been of about the same extent as the main body.

On December 8 the main cloud was slightly less long but broader than it had been on the preceding night; the subsidiary patch was not much changed. But both clouds had in the interval drifted 17° to the eastward and 3° or so to the north. Whether, therefore, the clouds were being propagated or not in a west-by-north direction each night, it would seem that either they or the stratum of air which generated them was drifting east by north at the rate of 17° + in twenty-three and a half hours, or at the rate of twenty-seven miles an hour.

17. Looking back now, with this motion in mind, in the records of the 12th December, § 11, we find that the place the clouds should have occupied on that date (longitude centre 302°—317°), if the same translation had been kept up, was under careful observation for such phenomena and nothing whatever was seen. Indeed, so comprehensive in extent were the observations, that any less speed of translation should also have caused the clouds to fall within the limits of inspection, and even a somewhat greater speed should have done so too.

On the 13th the place they should have reached was scrutinized. The observations covered from longitude centre 280° to 208°. Nothing showed. The same was done on the 15th, longitude centre 276°–285°.

We may conclude, I think, that the cloud formation had dissipated at some time between the 8th and the 12th.

18. The season of the martian year at which these clouds occurred is of interest. On December 7, 1901, it was April 26 in the northern hemisphere of Mars. The sun had gone north of the equator and was then overhead on the fourteenth parallel of latitude. The heat equator was a little behind it. Apparently then a current bearing the clouds was setting toward the heat equator from within the tropics to the south, where the season corresponded to the end of October. This current was deflected some eighty degrees to the east, and became an east-by-north wind.

19. Its origin may have been local. A little to the south of where the cloud first appeared lies the long east-and-west stretch of the Sabæus Sinus or Icarium Mare. Now the form of the cloud was of the same general shape—a cloud stretching east and west five times as far as it did north and south. The Icarium Mare is undoubtedly a great tract of vegetation, where moisture would be held and whence it could accordingly be given off. Arising there, either from seasonal or temporal cause, the vapor would gather into a cloud and proceed to float away over the desert regions to the north. If this, then, is what happened in the case before us, we may conceive the cloud as having been generated on the 6th of December over the Icarium Mare, rising to a height of thirteen miles, and then traveling east by north at about twenty-seven miles an hour off into the desert of Aeria, there to dissipate after an existence of three or four days. That it was a phenomenon of capricious not of regular production is shown by its not having been repeated—that is, it partook of the subtle unpredicability of cloud.

Stated Meeting, December 20, 1901.

Vice-President SELLERS in the Chair.

Present, 30 members.

Mr. C. Stuart Patterson read a memoir of the late Hon. Frederick Fraley, LL.D., President of the Society.

The meeting was adjourned by the presiding officer.